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RESEARCH ARTICLE



Do You See What I See? Emotional Reaction to Visual Content in the Online Debate About Climate Change

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ABSTRACT

This paper explores the visual echo chamber effect in online climate change communication. We analyze communication by progressive actors and counteractors involved in the public debate about climate change on Facebook, to address the possibility that visual content can bridge ideologically diverse communities. Specifically, we investigate whether visual content depicting protest serves this purpose. The findings reveal a small amount of shared visual content. Interestingly, the emotional reactions to this content for the most part diverge significantly, suggesting that pre-existing attitudes, such as climate ideological position, influence interpretation. Contrary to our expectations, however, we do not observe visual content representing protest activity bridging the two groups. This work posits the possibility of a two-fold (de)polarization around visual content that both connects and divides, which contributes to a more nuanced understanding of the social dynamics that create and sustain the echo chamber effect observed in online climate change debates.

KEY POLICY HIGHLIGHTS

- Even when taking into account visual communication, the online debate around climate change is characterized by the presence of echo chambers with only a small fraction of content that circulates among both climate activists and climate skeptics.
- In cases where the same visual content circulates within the two groups, the emotional reactions are often opposed, with reactions that are more defined by the pre-existing climate ideological alignment than with an actual engagement with the content.

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1 . Introduction

This paper explores the visual dimension of the hypothesized echo chamber in online climate discourse. The current consensus is that concerns about social media-defined echo chambers are either exaggerated or depend heavily on where and how these have been conceptualized and measured (Bruns, 2019; Vaccari & Valeriani, 2021; Yarchi et al., 2021). Nevertheless, the issue in the case of online climate communication seems complicated. The presence of separate echo chambers is a repeat finding (Bloomfield & Tillery, 2019; Brüggemann et al., 2020; Elgesem, 2019; Kaiser & Puschmann, 2017; vanEck et al., 2021), and recent work shows increasing polarization (Falkenberg

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et al., 2022). This said, there also seems to be more interaction between sides than commonly acknowledged (Treen et al., 2022; Williams et al., 2015), and there is a possibility that the findings of starkly separate spheres have much to do with how the matter has been studied.

We focus on the role of visual content in these processes. Images are recognized to be important in climate communication, helping to bring complex issues close to home, mobilize action, and shaping support for climate policy (Wang et al., 2018). The capacity to engage attention, establish an emotional connection, and convey complex information matters particularly on this kind of issue, which is often experienced as remote (Leiserowitz, 2006). Yet, the role of visual content in online climate discourse is still little understood.

We argue that visual content has the potential to contribute to a two-fold (de)polarizing dynamic in this context. On the one hand, it can cross climate ideological boundaries to become a focal point for engagement from opposing sides, thereby drawing separate spheres together. On the other hand, audiences may react to it in diverging ways, either due to different ideological, psychological and cultural predispositions, or because the content endorses or denigrates issues they care about or people like them. This means that engaging with common content can still underpin and amplify dynamics of antagonism and affect. We expect to see this pattern in relation to various kinds of visual content, but especially so with respect to images representing physical public protest such as street demonstrations, which can be expected to garner especially strong reactions in contentious contexts.

In order to examine the visual dimension of online climate discourse, and whether visual content supports echo chambers in this context, the study analyses the sharing of visual content across Facebook pages and groups that diverge in climate ideological stance. We ask the following questions: (1) Is visual content that is posted in the context of progressive action and activism also shared on pages and groups that oppose progressive climate action and activism? (2) Does the expressed emotional reaction to visual content change as it is shared in ideologically diverging pages and groups? (3) Do images of specifically public protest generate diverging reactions?

Our findings show that a small amount of visual content is indeed co-shared by ideologically distinct pages and groups, and that this content is the focus of emotional reactions that go in significantly different directions. This complements earlier findings about an echo chamber type pattern, but also suggests the presence of a (tenuous) common structural component. At the same time, since the shared visual content underpins emotional reactions that diverge between camps, it also suggests that seeing the same content does not straightforwardly imply common ground. Intriguingly, our expectation about the polarizing role specific to the visual representations of protest could not be confirmed.

2. Theoretical background

2.1. Polarization in online climate communication

Many studies of online climate communication indicate that the area is highly polarized (see van Eck (2024) for an overview). In line with overall findings about public opinion on climate change (Dunlap et al., 2016; Fisher et al., 2022), the online debate presents as a variant of ideological polarization (Fiorina & Abrams, 2008), with a (growing) distance between the extremes in climate ideological stance (Falkenberg et al., 2022). Broadly, the research shows that one side affirms the anthropogenic roots of the climate crisis and supports progressive action to address the problems, while the other side doubts the anthropogenic roots of climate change and/or supports delaying, redirecting or blocking progressive action on the issue. In this paper, we refer to the former side as *actors*, and to the latter as *counteractors* (for a detailed definition see Section 3).

The presence of ideological polarization seems to overlap with a structural or interactional dimension (Yarchi et al., 2021), with actors limiting their engagement to like-minded peers and disengaging with those that hold opposing views. Several studies show the climate actors and counteractors to be relatively disconnected and inward-looking, with both groups attending to their own

sources and little interaction between the groups. Bloomfield and Tillery (2019) find echo chambers in the circulation of content in climate contrarian groups on Facebook, and similar patterns have been found on both sides in the climate blogosphere (Brüggemann et al., 2020; Elgesem, 2019; Kaiser & Puschmann, 2017; vanEck et al., 2021). On Twitter, Williams et al. (2015) identify predominantly homophilic groups that communicate amongst themselves in climate hashtags, and Cann et al. (2021) find weakly connected components when studying media exposure via shared links.

In addition, research suggests the presence of (asymmetrical) antagonism against the other side, the hallmark of affective polarization (Iyengar et al., 2012). Those opposed to climate action are the most vociferous, yet their negative sentiments are primarily expressed in internal debate and their counterparts typically pay little attention in return. Tyagi et al. (2020) found that “skeptics” are more aggressive toward “believers” in climate hashtags on Twitter, Elgesem (2017) shows contrarian bloggers talking more about the progressive mainstream, and Elgesem and Brüggemann (2023) examine how activist Greta Thunberg became the object of highly emotional criticism by opponents of progressive climate action on German Facebook. There seems to be an overlap with a structural dimension also here: analyzing hoax accusations in the English-language climate blogosphere, Brüggemann et al. (2020) show both sides vilifying each other, but still not interacting directly.

Nevertheless, it remains unclear if the divides in online climate discourse are as sharp as they would first appear. While the evidence for online climate echo chambers is strong, it is also challenged by studies that call for greater attention to the type(s) of polarization at play, how the affordances of particular social media platforms underpin them, and the consequences of operationalization. In their Twitter study, Williams et al. (2015) found not only homophilic echo chambers but also mixed-attitude open forums when considering @mentions as opposed to followers and retweets. Similarly, Treen et al. (2022) argue that the characterization of online climate discourse as polarized is shaped by a focus on platforms with specific sets of affordances (predominantly Twitter). Focusing on Reddit, they discern polarization in themes and sources of information, but little evidence of echo chambers in network structure: all the communities are interlinked within a single-cluster giant component.

In this paper, we consider the possibility that some kinds of content may be engaged with and shared in ways that pull in different directions. We contend that such content may transcend boundaries to reach and engage online audiences that are climate ideologically opposed, thus becoming implicit points of connection that complicate the clean echo chamber view. However, we also posit that such content may simultaneously become a focal point for contrasting emotions in ideologically distinct realms, thus potentially becoming objects that support diverging issue perceptions and emotional dynamics. Visual content is of particular interest in this regard.

2.2. Mobilizing meaning and emotion via visual content in social media

A strong tradition of research addresses how visual content contributes to shaping citizen engagement with climate issues, action and policy (see Wang et al. (2018) for an overview), and it is already clear that the role of visual communication is amplified on social media platforms that are primed for attention and engagement. On Twitter, for example, messages with visual content such as photos, infographics, memes and videos are proportionally more shared (Goel et al., 2016). However, visual content also has a more complex role to play.

For the large-scale dynamics at issue in this paper, the key is not the isolated image, but the reactions, repetitions and negotiations around it. While strategic actors such as advocacy organizations and activists extend their communication efforts in social media (Boulianne et al., 2020; Hopke & Hestres, 2018; Qian et al., 2024), it is also worth noting the role that platforms and audiences play in the visibility of the content and the affective practices (Wetherell, 2012) that develop around it. User engagement feeds the algorithmic curation of visibility and, together with platform signals of attention and engagement (e.g. metrics, comments, emoticons, likes, and reshares), leave traces that contribute to the emotional framing that fresh audiences encounter. This is important, since

engagement signals impact user perceptions of salience (Spartz et al., 2017), and emotional framing plays a part in how (visual) information shapes public perception of climate change (Feldman & Hart, 2016; Meijnders et al., 2001; Nabi et al., 2018; Sanford et al., 2023; Yuan & Lu, 2020).

With this in mind, it is crucial to consider the possibility that visual content can transcend boundaries to forge connections but also deepen divides. This can happen for two reasons. For one, audiences are likely to engage differently with content that overtly attacks or supports groups and positions with which they identify and agree (or oppose). Studies on right-wing nationalist communication illustrate how visual content is simultaneously used in both inward-looking processes of meaning-making and out-group attacks. For example, Hokka and Nelimarkka (2020) trace the affective economy (Ahmed, 2004) of how national-populist thinking is reinforced through images that evoke fear, anger, resentment and distrust of immigrants and refugees in groups on Finnish Facebook. They suggest that the visual themes gain power in transnational travel, even if translation and reframing are required for local fit and fight (see also Doerr, 2017; McSwiney et al., 2021). Ross and Rivers (2019) present examples of such adaptation work in the online climate debate in their study of how “convinced” and “skeptical” sides adapt the same popular memes and media frames to their own logics.

A second reason is that even less polemical visuals may spark distinct patterns of attention, reaction, and engagement among audiences with differing ideological, psychological, or cultural predispositions (Domke et al., 2002). This is what Von Sikorski (2022) describes as visual polarization: when the identical image affects audiences with different prior attitudes in distinct ways and thereby contributes to polarized issue perceptions. While individual-level reactions cannot be predicted, previous research has shown the role of predispositions along three paths. The first is with respect to subtle visual cues, such as background in-group cues or darkness/lightness cues, which have respectively been shown to prime preexisting values such as patriotism and interact with media trust in assessments of political candidates (Dan and Arendt, 2021, 2024; Von Sikorski, 2022). The second is with respect to emotional cues such as hope, fear, anger, and aggression in the actual visual content or its accompanying text and comments (Feldman & Hart, 2016; Yuan & Lu, 2020). A third path runs via the polysemantic potential of motifs and frames. While cross-cultural audiences respond similarly to some classic climate visual themes, climate and political ideological predisposition seem to condition reactions (Chapman et al., 2016).

In combination, the significance of both visual strategies and diverging reactions is likely to be more salient in online contexts that involve contention. Under fraught conditions, valence diverges for visual themes that become associated with partisan actors (Feldman & Hart, 2016), and as noted, such divergences can become enhanced in the affective practices around the content. Further, contentious contexts may involve actual protests, and images of protest stand out in their potential to be both empowering and divisive. While indications of successful mobilization encourage supporters (Casas & Williams, 2019; Doerr et al., 2013), evidence of a movement gaining ground also incite the countermovement (Meyer & Staggenborg, 1996; Staggenborg & Meyer, 2022). Moreover, experiments involving protest imagery show asymmetrical reactions along psychological or ideological profiles (Gutting, 2020), and partisan alignment in disapproval of (even nonviolent) out-group protest (Croco et al., 2023). While previous research has also identified visual features that tend to attract online engagement across the board (e.g. the presence of human faces, Li and Xie (2020)), protest images are a likely case in which the two-fold dynamic of connection and division would appear.

2.3. The potential for two-fold (de)polarization around visual content in online climate communication

The discussion in the previous sections implies a number of expectations about the role of visual content in online climate communication. If climate ideologically diverse social media audiences engage with the same visual content, we expect this to occur with differences in degree and valence

of engagement such as shares, comments, and codified emotional responses (e.g. the Love, Angry or Laughter buttons on Facebook). Moreover, expressed reaction to content that is clearly associated with one side is likely to be asymmetrical: not only will each side engage more with content from their own side in online climate communication, counteractors are likely to focus more and with greater hostility on actor content than the other way around.

Further, in a contentious area such as this, we expect images related to mobilization (e.g. protest) to be particularly inflaming in ways that will leave explicit traces of this kind. Previous work on visual climate discourse on Twitter and Instagram finds protest images to be prevalent alongside other content types such as data visualizations, infographics and memes, and images of nature and technology (Mooseder et al., 2023; Qian et al., 2024). While protest images make up only a small portion of the data, they attract notable engagement: In ten years of #climatechange on Twitter, protest pictures are the proportionally most shared (Mooseder et al., 2023). Differentiating within this engagement, we assume that actors are likely to be supportive of protest on their own side, but that counteractors may seize on such images with reactions such as anger, aggression or a mocking stance.

More broadly, the previous discussion also suggests that analytical focus on the visual dimension has the potential to add a distinct perspective on the issue of echo chambers and polarization in online climate discourse. If visual content offers common focal points across climate ideological divides while supporting distinct patterns of emotional engagement, such image-focused dynamics would both complement and complicate the notion of echo chambers in online climate discourse by suggesting points of connection and divergence that have not been accounted for.

Moreover, taking the visual dimension into account brings us back to the underlying discussion of how polarization is conceived and measured in the study of online climate communication and why it matters. The phenomenon in focus here hinges on audiences associating different substantive meaning and sentiments with the same visual content. To capture the expressed emotional response, a dichotomy or linear spectrum of opposites (such as anger/joy, love/hate) is not always appropriate, since audience reactions do not always run on the same scale (e.g. pitting anger against solidarity, but also encompassing different directions such as sadness, fear, or amusement). As we unpack further in the method section, this entails a different approach from the classic models that focus on distance in positional extremes (e.g. as in ideological polarization; Fiorina & Abrams, 2008), or intensity (e.g. as in the “feeling thermometer” approach to affective polarization; Iyengar et al., 2012).

2.4. Research questions

Given this theoretical backdrop, we ask the following research questions in order to analyze the visual dimension of online climate discourse, and in particular whether visual content supports signs of echo chambers between pages and groups with different climate ideological positions on Facebook:

RQ1 Is visual content posted on Facebook pages and groups that are active in the context of progressive climate change action and activism also shared on ideologically diverging pages and groups?

RQ2 Does the expressed emotional reaction received by visual content shared by climate action supporting pages and groups change when it is shared on ideologically diverging Facebook pages and groups?

RQ3 Does visual content representing physical protest for climate action generate emotional reactions that are different from the ones generated by other types of visual content, when shared online by climate action supporting pages and groups? And is this different from the reaction it receives from ideologically diverging groups?

3. Data and method

The data builds on online communication in a curated list of public Facebook pages and groups that have been manually coded as actors or counteractors. The label “actor” refers to those who advocate

for more urgent action against climate change, and “counteractor” refers to those who support climate change denialism and/or object to progressive action on climate change. Besides being the largest social network site in the world, Facebook is used by both groups (Bloomfield & Tillery, 2019; Tandoc & Eng, 2017). Moreover, Facebook groups and pages allow a wide range of reactions to the content that gets posted, which in turn enables an exploration of the audiences’ emotional reactions. We here focus on a single platform. While a comparative perspective across multiple social media would be of extreme interest, social media platforms are largely defined by their affordances as well as localized cultures and practices, making direct comparisons both technically and theoretically challenging.

We situate this study in relation to European climate actors, which provides both a more transnational and a more locally situated context than the generic English-language setting that is common in the study of online climate discourse. Our initial list of pages and groups was compiled by a team of domain experts from the PolarVis project through a multi-stage process with the goal of including not only the major organizations that are active and visible in the public debate about climate change, but also the galaxy of local groups, communities and semi-formal organizations that play a role in shaping the debate and its public perception (Castro et al., 2016; Hoppe et al., 2016). First, the experts adopted an inclusive filter by adding pages and groups even if they were only loosely connected with the topic. Then, by looking at their latest posts, we removed the more marginal groups operating at the topical borders of the climate debate (e.g. advocating for better cycling infrastructure or food self-production), if the majority of their content was deemed to be off-topic. The final list of pages and groups counts 423 European public Facebook pages and groups from the Austrian/German region (267 entities), the Nordic countries (87 entities), and Great Britain (46 entities), in addition to international actors that cannot be geographically associated to a single European country (e.g. Fridays for Future International).

Of those 423 Facebook entities, 258 have been manually labeled as actors and 165 have been labeled as counteractors. We designated as *actor* pages or groups that implicitly or explicitly in profile and/or recent posts affirm anthropogenic climate change as problem, and/or support progressive action on climate change, and/or support civic mobilization (e.g. protest action) to this effect. We labeled pages and groups as a *counteractor* if they implicitly or explicitly in their profile and/or recent posts deny anthropogenic climate change as problem, and/or reject progressive action on climate change, and/or reject civic mobilization (e.g. protest action) for progressive action on climate change.

To build the database of visual content for this study, we first used CrowdTangle to collect all the public posts shared by the 258 actors between July 1, 2023 and October 15, 2023. We selected a time period in which there would be protest action in the form of climate strikes, but avoiding the more dispersed contention that occurs during the COP summits. We expect this to be a conducive case to find contention related to protest images. 3,500 of the 7,256 collected posts contained visual content, identified as a photo element by the CrowdTangle API. This technical detail also defines the type of content that we take to be visual content: We consider any kind of Facebook content that is uploaded as an image in a post to be visual content, since it is displayed as such to the user. This means that we also include images representing text or combinations of texts and pictures (e.g. memes) as visual content.

We then used the CrowdTangle API to retrieve all¹ the other Facebook posts that shared visual content contained in our initial 3,500 posts. This amounted to 12,507 posts made by an extended set of 5,436 public Facebook groups and pages (including the 258 originally coded as actors and 39 of the originally coded counteractors). Importantly, co-sharing should here be understood to imply co-exposure to the same visual content, rather than visual content propagating directly from actors to counteractors. More specifically, it encompasses sharing as generated through any of the mechanisms allowed by Facebook, e.g. directly sharing a post from the initial list of pages and groups, sharing a post not in our initial list but linking to the same content, or posting a link to the same visual content without directly sharing another post. Moreover, it concerns sharing the

link to the same image, as opposed to the actual image itself. Different pages or groups may share the same picture through multiple links, but this analysis only encompasses the cases in which they post the same link, which is what happens when the Share button is clicked on Facebook.

Given this dataset of images, the analysis is based on three main elements: (a) an ideological score, to categorize pages and groups that were not present in our initial list along an ideological axis that goes from actors to counteractors; (b) a protest score, to define if an image represents a physical protest; and (c) an emotional reaction score, to measure how much the online reaction to an image leans toward positive or negative feelings.

3.1. Ideological score

The majority of the 5,436 pages and groups that shared the visual content posted by our initial list of 258 actors and counteractors were not in that initial, manually coded, list. To address this problem, we adopted a method tested by Arminio and Rossi (2024). The method relies on the intuition that one can leverage the word embeddings of the textual content produced by several pages and groups to cluster them into thematically and ideologically coherent sets. To do this, we collected the last 100 Facebook posts for each page and group that shared the visual content (including those for which we had manual labeling). We then translated all the textual content into English using the Google Translate API and calculated the word embeddings per each post using the ada-002 model made available by OpenAI. Word embeddings are a way to represent text as multidimensional vectors and are commonly used to measure similarity between texts or their sentiment. Given the high number of dimensions available with contemporary models (ada-002 outputs 1536 dimensions per embedding) they are able to numerically represent not only the topic of a text but also the words and adjectives used for it (Kenter & De Rijke, 2015). The embeddings for every post have then been reduced to a single dimension with the t-SNE method (vander Maaten & Hinton, 2008) and an average value for each page/group has been calculated. This allowed us to estimate a score (*ideological score*) per each entity that represents both the topics that are usually discussed by that entity as well as the tone with which those are discussed.

Due to the reliance of the method on textual content, a large number of pages and groups (4,522) did not receive an ideological score because they either did not produce content in a language covered by the Google Translate API or did not produce textual content at all (i.e. only sharing visual content, links, or videos). These groups seem primarily dedicated to sharing and resharing visual content, and seem to exist mainly to collect members through visual clickbait. They do not otherwise appear to have anything in common: they vary in size, geographical origin and type of content shared. These pages and groups with unknown ideological scores are reported in Table 2 but were excluded from the statistical testing.

To validate this labeling, we used the manually coded pages and groups that were present both in our initial list and in the list of pages and groups that shared visual content from actors. This included 29 counteractors. On this ground truth, our validation obtained an F1 score of 0.85.

3.2. Detection of images of protest

Once the shared visual content was identified, we determined which parts represented some kind of physical form of protest, such as violent or non-violent scenes of protest performance or civil disobedience (e.g. bodily roadblocks or activists glueing themselves to artworks), street demonstrations, protest occupation, and close-ups of activists involved in such activities (e.g. holding protest signs). To do so, we used the model developed by Won et al. (2017). This model is based on a Convolutional Neural Network specifically trained for visual representation of protests producing a *protest score* that can be used to classify images. This model has been previously used in a number of studies to classify the visual content of protests shared on social media (Rossi et al.,

Table 1. Examples of images at various levels of protest score.

Score	0.9	0.8	0.7	0.6	0.5
					

2023; Won et al., 2017). This model has been trained on data that include a very specific visual esthetic (and tactic) of “protest”. Thus, the final protest score can be read as a measure of how close a specific image gets to the model’s ideal-typical image of protest, which centers on a group of people standing or marching on a street with signs. Looking at Table 1 should clarify this concept, which comes with limitations that we will return to in Section 5.

To tune the model to our context, we created a validation dataset containing 159 images. These images were obtained as follows: 10 were manually selected examples of protests from our dataset, 60 were the results of the query “climate change protest” on Google image search, from which we selected photos matching our definition, and 84 were images shared by our actors that we manually checked to determine that they did not represent any protest activity. We used this validation dataset to identify the optimal threshold for the protest score to label a picture as a protest picture. We iterated through all the possible values of protest score and we set the optimal level to .70, which produced a Precision of 1.00, a Recall of .84 and an F1 score of .91. We then calculated the protest score for all the images in the dataset and labeled the images with protest score equal or higher than .70 as “protest images”. Manual inspection of the results confirmed our decision.


3.3. Emotional reaction score

We focus on expressed emotional reactions as codified by the Facebook response buttons. To evaluate how Facebook users reacted to the visual content, we use the emotional polarization score defined by Muraoka et al. (2021). The emotional polarization score leverages the reactions that Facebook allows users to express toward any content they see on the platform. It measures the relative share of Angry reactions over Love reactions for each post. It is calculated as:

$$\frac{\text{Proportion of Angry reactions} + 1}{\text{Proportion of Love reactions} + 1}.$$

A score lower than 1 indicates that Love reactions dominate over Angry reactions, while a score greater than 1 means the opposite. It is worth highlighting, as done by the original authors, that this score does not consider the intensity of the overall emotional response—that would instead have been measured by considering the absolute number of reactions rather than proportions. Moreover, the measure comes with some caveats: First, it focuses on only two types of reactions out of the many enabled by the social media platform. Second, it is possible that considering only Love might underrepresent the positive reactions since the design of the Facebook interface offers a greater range of positive than negative reactions. These concerns should be kept in mind when we interpret the results in the following sections, but it should also be noted that the original authors of the metrics tested it quite extensively and found it robust. Third, while Muraoka et al. (2021) call their measure “emotional polarization”, we will refer to it as *emotional score*, because we use it to compare reactions to the same image in different posts and not to examine polarized reactions to the same post. In particular, we apply the emotional score to the content shared on different pages or groups in order to measure the diversity in emotional reaction to the same content depending on the climate ideological alignment of the context in which the content is shared.

Table 2. Reshares ($N = 12,507$) of posts published by our initial set of actors. Percentage values refer to the total number of posts within the specific category (e.g. 1.7% of the 12,507 reshared images represents visual protest and were co-shared by actors).

 Set of images shared by selected <i>actors</i>	Co-shared by (type of actor)	Represents visual protest
	<i>actors</i>	YES: 1,7 % NO: 41,4 %
	<i>counter actors</i>	YES: 0,0 % NO: 3,1 %
	<i>not labelled</i>	YES: 1,0 % NO: 52,7 %

4. Analysis

The first research question speaks directly to the issue of echo chambers in the context of the public debate around climate change. It asks if Facebook pages and groups that we assess as actors and counteractors in this space share the same visual content. We investigate the question by measuring the volume of visual content shared by actors that was also shared by counteractors. Recall that we here perform the analysis not at the level of the picture itself but at the level of the link to the picture shared on Facebook.

Table 2 shows the percentage of visual content representing and not representing visual protest that is co-shared by actors, counteractors, and unlabeled pages and groups (these are the pages and groups that we were unable to label on the ideological scale, as described in Section 3.2). It is evident that the vast majority of co-sharing takes place within ideologically homogeneous entities. This finding is in keeping with an echo chamber scenario where communication remains largely defined by ideologically homogeneous parts of the network. Nevertheless, we do observe a small fraction of visual content that is indeed co-shared and constitutes what we can conceive of as a bridge across ideologically diverse communities.

This leads us to our second research question, which addresses whether content triggers different expressed reactions when it is shared within actor or counteractor online spaces. For this question, we leverage the emotional reaction score introduced in Section 3.1. The emotional reaction score measures the proportion of reactions that are Angry or Love and gives us a measure for how much the expressed reactions of the public of that Facebook group or page lean toward one feeling over the other. Figure 1 shows a statistically significant difference² between the reactions that the same content receives in actor space and counteractor space. Although the effect is small, it is clear that the reaction leans toward Love when visual content is shared by actors, but that this effect largely dissipates when the visual content is shared by counteractors, with reactions, in that case, concentrating on a neutral score.

These results show that there are differences in the reception to the content that depend on the context in which it is shared, which is worth exploring further. Leveraging the emotional reaction score we can measure, per each visual content that is co-shared among counteractors, both the direction of the change in reaction to an image (e.g. from mostly receiving Love reactions to receiving a more balanced amount or even shifting toward Anger reactions), as well as the extent of this

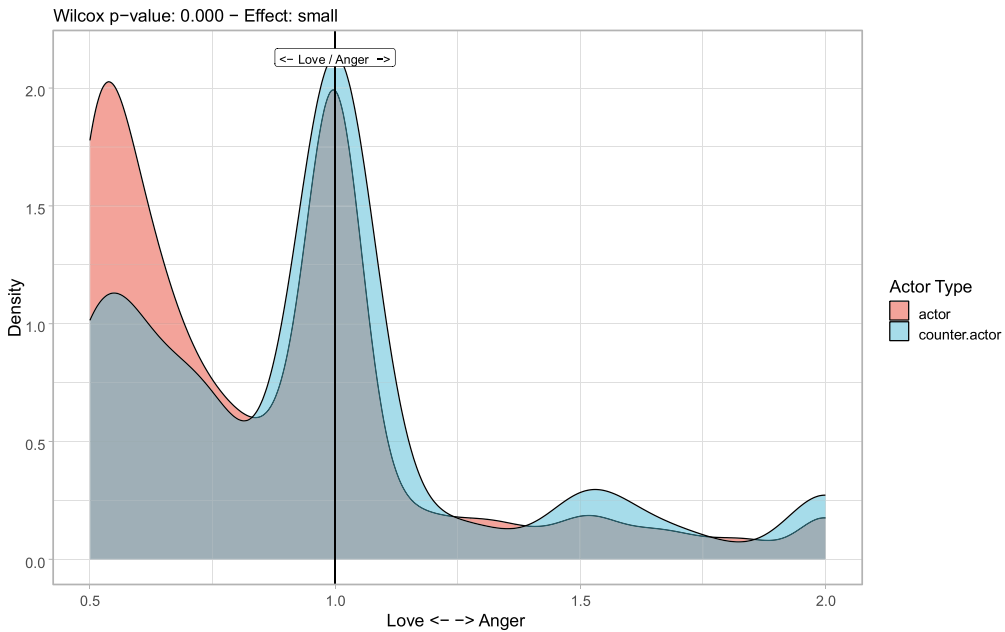


Figure 1. Emotional reaction score for visual content shared by actors and counteractors ($N = 4118$ posts)

change. To do this, we take the emotional reaction score that the content received when shared by actors as the starting point, and the emotional reaction score received when shared by the counteractors as the end point. In the following plot, “toward anger” should be read as content that has a higher (closer to Anger) emotional reaction score when shared by counteractors than when it is shared by actors.

Figure 2 shows the amount of visual content that changes emotional reaction score when shared by counteractors, as well as the intensity of that change. It is interesting to observe that the reception to the vast majority of content changes emotional value (e.g. shifting from leaning toward Love, to leaning toward Anger and vice versa), but also that the extent of this change is significantly stronger when content changes from an emotional reaction leaning toward Love to an emotional reaction leaning toward Anger.

So far, answering our first two research questions, we see that although most visual content shared by actors is not shared in ideologically opposed parts of the Facebook network, a small fraction is in fact co-shared by both actors and counteractors. Although only a fraction, we also see that this co-sharing corresponds to a change in the reactions that the content generates, with a substantial decrease in positive Love reactions and a moderate increase in Anger reactions.

Turning to the last research question, we now consider the role played by visual representations of protest. The underlying intuition is that in this type of contentious context, images of physical protest should have a larger emotional effect compared to other types of content that reach ideologically opposed parts of the Facebook network.

The results go against our expectations on this point. **Figure 3** shows the emotional reaction scores for protest and non-protest images shared by our initial group of actors. We observe a statistically significant shift toward Love reaction for images representing physical protest. We interpret this to mean that images representing protest activities elicit support among like-minded users.

However, as we see in **Table 2**, there is not a single image representing physical protest in the content co-shared by counteractors. Visual content representing protest for climate action receives positive emotional reactions when shared on the Facebook pages or groups of pro-climate action actors, but this does not spark a reaction or result in an increased potential to breach the echo

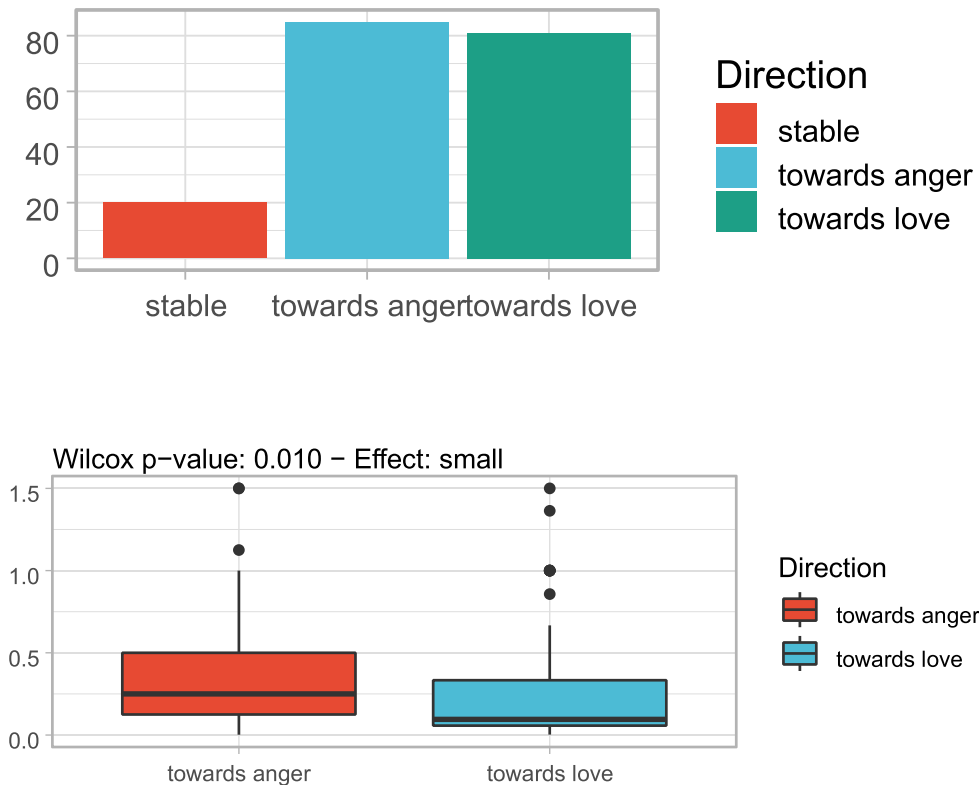


Figure 2. Direction and extent of change in emotional score for visual content co-shared by counteractors ($N = 186$). Wilcox p -value: 0.010 – Effect: small.

chamber barrier. On the contrary, in this data, representations of protest do not enter the counter-actor network at all.

At this point, although this paper overall takes a quantitative approach, it is useful to discuss qualitative examples of the dynamic we are describing, both as a sanity check and as a way to more fully grasp the phenomena we are observing. While visual content representing physical protest does not reach counteractors, we saw that other content does, and that this content generates different displays of emotional reaction depending on where it is shared. We here provide two examples that illustrate emotional transitions in contrasting directions.

Figure 4 exemplifies an image that was hated when shared among the actors and loved when shared among the counteractors. The image has the esthetic of a meme and was shared among Swedish actors and counteractors. It shows an elderly man with a face that is partially covered with what looks like black paint and the text “In Great Britain they throw black paint to the climate activists that stop the traffic by sitting on the roads. Thanks for the tip!” Reactions were mostly amused when the content was shared on the counteractor side, while the image was taken as an example of the violence of the “other side” when shared among the actor groups.

The expressed reactions to the image in Figure 5 run in the opposite direction. The image refers to a recent installation of large wind turbines in Germany and comes with a text that summarizes the incentives that have made the local community welcome the project. When shared on actor pages the comments were overwhelmingly positive and included statements like “Best Practice!” or “So was nennt man Fortschritt.”³ When shared in a counteractor group the tone of the comments changes radically and includes critical or negative comments such as “Stinkt nach Bestechung”⁴ or “Wenn es für diesen Wahnsinn keinen Widerstand gibt, kann es nur an der Dummheit und

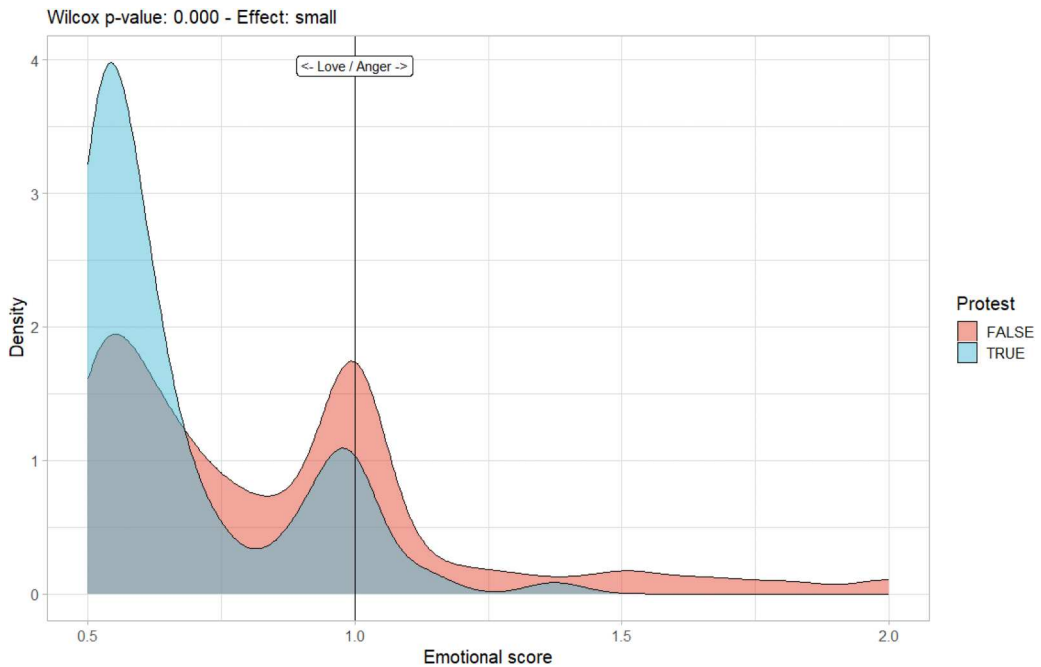


Figure 3. Emotional scores for protest ($n = 89$) and non-protest ($n = 2735$) images shared by actors.

Naivität der Schipkauer liegen,”⁵ together with longer comments detailing the perceived limitations or economic problems of wind energy.

These examples are relevant on two levels. First, they illustrate the polysemantic nature of images and how audiences approach visual content from the standpoint of prior attitudes regarding the issue and each other. This is what makes it possible for audiences to find an image such as [Figure 4](#) amusing or offensive depending on where they are positioned on the issue and in the contentious relationship with the other side. Second, these examples indicate that the emotional reaction score measure was successful in capturing such complex qualitative dynamics by flipping direction when the images were shared in diverging ideological spaces.

5. Discussion

This paper has examined the visual dimension of the purported echo chambers in online climate discourse. Analyzing communication in European climate discourse on Facebook over an extended period of time, we investigated to what extent visual communication provides common ground between opposing camps. Our findings show that actors and counteractors share a small set of visual content, and that this content elicits diverging reactions that correlate with the ideological positions of the respective online spaces.

Contrary to our expectations, there was no evidence that counteractors co-shared any images representing physical protest, a type of image we had expected to be the object of strong and highly opposing reactions if shared. It is possible that a factor in the absence of co-sharing in this case could be that the global climate strike movement—which had received a large amount of attention in the preceding years—was losing momentum by the time of our data collection and may therefore have been less in focus as a target for its opposition. More concretely, it may reflect two key limitations already highlighted about our approach: Our method for identifying protest centers on mass street demonstrations, whereas the data was collected at a time when attention may have shifted to include select civil disobedience tactics. Meanwhile, we analyze image links, which likely

I Storbritannien slänger man svart färg på miljöaktivister som sitter i vägen för trafiken. Tack för tipset!



Figure 4. An image in the dataset that saw a changing polarity in reactions depending on the ideological alignment of the Facebook space in which it was shared.

underestimates the actual presence of co-shared images. Still, our unexpected null result on this question calls for further research to see if it holds with other operationalizations, over different time periods, and across other platforms that support different visual climate communication cultures (Pearce et al., 2020; Qian et al., 2024). It will also be relevant to analyze and compare reactions to the other types of categories of visual content that have been shown to be prevalent in online climate communication (Mooseder et al., 2023; Qian et al., 2024).

Overall, this set of observations complements the theoretical debate we outlined in Section 2. That only a small fraction of visual content is shared confirms the presence of an echo chamber-type structure also when it comes to the visual dimension in online climate discourse. It seems climate actors and counteractors move in largely distinct visual worlds (on Facebook), and this pattern is in keeping with the text-based studies of online climate communication (Bloomfield & Tillery, 2019; Kaiser & Puschmann, 2017; Williams et al., 2015). As most large-scale analyses have been based on Twitter or blogosphere data, our study extends this work by presenting evidence supporting the pattern also on Facebook.

Importantly, however, our findings also nuance the debate by confirming the workings of a two-fold dynamic associated with the visual content that is in fact shared. In the tenuous bridge of co-shared content, we observed how it triggers different, often opposing, reactions in the respective spaces, whether underpinned by different climate ideological positions or direct conflict between



Figure 5. Another image in the dataset that saw a changing polarity in reactions depending on the ideological alignment of the Facebook space in which it was shared.

the groups. Methodologically, this lends support to the notion that polarized patterns that come into view depending on the aspect we examine (Treen et al., 2022; Williams et al., 2015). Substantively, it suggests that the sheer presence of a network giant component, where present, does not in itself provide or give evidence of meaningfully shared ground. What is more, and deserving of further research, it suggests that shared (visual) sources that simultaneously connect and divide can harbor seeds for contentious commentary and emotional framing that underpin further polemics among new audiences in online discourse over time.

More broadly, the findings confirm that in order to gain a full understanding of the dynamics underpinning echo chambers on social media, we need to connect the phenomenon more firmly with the study of predisposition and confirmation bias (Del Vicario et al., 2017; Modgil et al., 2024). While recent research has pointed to the role played by algorithmically curated feeds in the creation of informational echo chambers (González-Bailón et al., 2023; Guess et al., 2023), we emphasize that exposure to alternative sources is only part of the story. Analyzing contact and exposure need to be matched by attention to how ideological position and other predispositions mediate perceptions of and reactions to (visual) content.

In addition to its empirical and theoretical contribution, this paper has introduced a number of methodological innovations in the computational analysis of visual content and estimating the ideological alignment of online entities. While these methods have clear limitations—which we acknowledge in the following section—they open a wide range of research possibilities when analyzing social media data that is both increasingly central to political communication and increasingly visual in nature.

5.1. Limitations

The complexity of social media data and the computational nature of the methods underpinning this paper present some limitations that should be acknowledged and understood. For one, despite having monitored four months of data, the content representing physical protest turned out to be quite scarce and it is possible that the response to such content could follow different patterns in periods in which protest activity is more intense or characterized by more extreme acts of protest. Further analysis of data collected over time is needed to confirm or reject the trends that we have observed.

Second, our results are clearly dependent on the metrics that we have adopted to measure complex concepts such as ideological position and the emotional reaction generated by visual content. In particular, the emotional reaction (or emotional polarization) score, while used and validated in previous research (Kaur et al., 2019; Muraoka et al., 2021), has limits when applied to our context. For one, it does not capture textual comments that might contain more nuanced opinion about the post in question. Moreover, it reduces the polarization dynamic to only two reactions, Love and Anger, ignoring all other reactions allowed by Facebook. While a platform design that encourages positive and supportive reactions over what is perceived as negativity is clearly not neutral to the data it produces, it is also possible that users adopt different ways to convey their discontent, e.g. laughing as a way to mock what the image represents. Additionally, reducing opinions to an emotional expression makes it impossible to properly identify the actual “target” of that feeling. For example, if a protest image shared within an activist group were to represent the police arresting protesters, some within the group might express their solidarity through love toward their fellow activists while others might express their anger by hating the police action.

Third, when moving from one ideological space to another, images can easily be explicitly re-framed in their textual description. In this study, we are unable to distinguish if the expressed emotional reaction is due to the audience reacting to the visual content, to the text or – as is most likely – to both. While the textual framing and the visual interpretation are undoubtedly connected, it is possible to imagine cases where images would not immediately generate a clear emotional reaction and where a re-framing operation would lead the audience toward a specific emotional stance.

Fourth, as noted, relying on the content link is a sound way of identifying the same visual content, but it also likely underestimates the volume of visual content actually shared. Diverse links may potentially be used to share a large amount of identical content. Unfortunately, the identification of identical images is a non-trivial task from a computational perspective, since very small changes to an image file (e.g. when an image is slightly cropped or has a different file format) tend to be identified as two distinct images by the most commonly used algorithmic approaches such as image hashing (Monga & Evans, 2006) or color histogram (Liu & Yang, 2013). There is room for further research also here.

Notes

1. Limited to the content available via Crowdtangle, e.g. no private posts are included.
2. In this and the following analysis, given the non-normal distribution of the scores, we performed a Wilcoxon test for statistical significance and effect size (Tomczak and Tomczak, 2014).
3. “That’s what you call progress”.
4. “Stinks of corruption”.
5. “If there is no resistance to this madness, it can only be due to the stupidity and naivety of people from Schipkauer”.

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References

- Ahmed, S. (2004). Affective economies. *Social Text*, 22(2), 117–139. https://doi.org/10.1215/01642472-22-2_79-117
- Arminio, L., & Rossi, L. (2024). Which reveals ideology better? Comparing self-presentation and public rhetoric in the Facebook climate debate via embeddings analysis. In L. M. Aiello, T. Chakraborty, & S. Gaito (Eds.), *The 16th international conference on advances in social networks analysis and mining (ASONAM 2024). lecture notes in computer science* (Vol. 15213). Springer.
- Bloomfield, E. F., & Tillery, D. (2019). The circulation of climate change denial online: Rhetorical and networking strategies on Facebook. *Environmental Communication*, 13(1), 23–34. <https://doi.org/10.1080/17524032.2018.1527378>
- Boulianne, S., Lalancette, M., & Ilkiw, D. (2020). “School strike 4 climate”: Social media and the international youth protest on climate change. *Media and Communication*, 8(2), 208–218. <https://doi.org/10.17645/mac.v8i2.2768>
- Brüggenmann, M., Elgesem, D., Bienzeisler, N., Gertz, H. D., & Walter, S. (2020). Mutual group polarization in the blogosphere: Tracking the hoax discourse on climate change. *International Journal of Communications*, 14, 24. <https://doi.org/10.46300/9107.2020.14.5>
- A. Bruns. (2019). *Are filter bubbles real? Digital futures*. Polity Press.
- Cann, T. J. B., Weaver, I. S., & Williams, H. T. P. (2021). Ideological biases in social sharing of online information about climate change. *PLoS One*, 16(4), e0250656. <https://doi.org/10.1371/journal.pone.0250656>
- Casas, A., & Williams, N. W. (2019). Images that matter: Online protests and the mobilizing role of pictures. *Political Research Quarterly*, 72(2), 360–375. <https://doi.org/10.1177/1065912918786805>
- Castro, P., ali Uzelgun, M., & Bertoldo, R. (2016). Climate change activism between weak and strong environmentalism. In Caroline Howarth & Eleni Andreouli (Eds.), *The social psychology of everyday politics* (pp. 146–162). Routledge.
- Chapman, D. A., Corner, A., Webster, R., & Markowitz, E. M. (2016). Climate visuals: A mixed methods investigation of public perceptions of climate images in three countries. *Global Environmental Change*, 41, 172–182. <https://doi.org/10.1016/j.gloenvcha.2016.10.003>
- Croco, S. E., Cunningham, K. G., & Vincent, T. (2023). Protests and persuasion: Partisanship effect on evaluating nonviolent tactics in the United States. *Journal of Peace Research*, 60(1), 26–41. <https://doi.org/10.1177/00223433221146577>
- Dan, V., & Arendt, F. (2021). Visual cues to the hidden agenda: Investigating the effects of ideology-related visual subtle backdrop cues in political communication. *The International Journal of Press/Politics*, 26(1), 22–45. <https://doi.org/10.1177/1940161220936593>
- Dan, V., & Arendt, F. (2024). Visuals as identity markers in political communication on social media: Evidence for effects of visual cues in liberals, but not in conservatives. *Mass Communication and Society*, 1–27. <https://doi.org/10.1080/15205436.2024.2333404>
- Del Vicario, A., Scala, G., Caldarelli, H., Stanley, E., & Quattrocioni, W. (2017). Modeling confirmation bias and polarization. *Scientific Reports*, 7(1), 40391. <https://doi.org/10.1038/srep40391>

- Doerr, N. (2017). How right-wing versus cosmopolitan political actors mobilize and translate images of immigrants in transnational contexts. *Visual Communication*, 16(3), 315–336. <https://doi.org/10.1177/1470357217702850>
- Doerr, N., Mattoni, A., & Teune, S. (2013). Toward a visual analysis of social movements, conflict, and political mobilization. In Nicole Doerr, Alice Mattoni, & Simon Teune (Eds.), *Advances in the visual analysis of social movements* (pp. xi–xxvi). Emerald Group Publishing Limited.
- Domke, D., Perlmutter, D., & Spratt, M. (2002). The primes of our times?: An examination of the ‘power’ of visual images. *Journalism*, 3(2), 131–159. <https://doi.org/10.1177/146488490200300211>
- Dunlap, R. E., McCright, A. M., & Yarosh, J. H. (2016). The political divide on climate change: Partisan polarization widens in the U.S. *Environment: Science and Policy for Sustainable Development*, 58(5), 4–23. <https://doi.org/10.1080/00139157.2016.1208995>
- Elgesem, D. (2017). Polarization in blogging about the Paris meeting on climate change. In Giovanni Luca Ciampaglia, Afra Mashhadi, & Taha Yasseri (Eds.), *Social informatics: 9th international conference, SocInfo 2017, Oxford, UK, September 13–15, 2017, proceedings, part I 9* (pp. 178–200). Springer.
- Elgesem, D. (2019). The meaning of links: On the interpretation of hyperlinks in the study of polarization in blogging about climate change. *Nordicom Review*, 40(s1), 65–78. <https://doi.org/10.2478/nor-2019-0014>
- Elgesem, D., & Brüggemann, M. (2023). Polarisation or just differences in opinion: How and why Facebook users disagree about greta thunberg. *European Journal of Communication*, 38(3), 237–254. <https://doi.org/10.1177/02673231221116179>
- Falkenberg, M., Galeazzi, A., Torricelli, M., Di Marco, N., Larosa, F., Sas, M., Mekacher, A., Pearce, W., Zollo, F., Quattrociochi, W., & Baronchelli, A. (2022). Growing polarization around climate change on social media. *Nature Climate Change*, 12(12), 1114–1121. <https://doi.org/10.1038/s41558-022-01527-x>
- Feldman, L., & Hart, P. S. (2016). Using political efficacy messages to increase climate activism: The mediating role of emotions. *Science Communication*, 38(1), 99–127. <https://doi.org/10.1177/1075547015617941>
- Fiorina, P., & Abrams, S. J. (2008). Political polarization in the American public. *Annual Review of Political Science*, 11(1): 563–588. <https://doi.org/10.1146/annurev.polisci.11.053106.153836>
- Fisher, S. D., Kenny, J., Poortinga, W., B’ohm, G., & Steg, L. (2022). The politicisation of climate change attitudes in Europe. *Electoral Studies*, 79, 102499. <https://doi.org/10.1016/j.electstud.2022.102499>
- Goel, S., Anderson, A., Hofman, J., & Watts, D. J. (2016). The structural virality of online diffusion. *Management Science*, 62(1), 180–196. <https://doi.org/10.1287/mnsc.2015.2158>
- González-Bailón, S., Lazer, D., Barberá, P., Zhang, M., Allcott, H., Brown, T., Crespo-Tenorio, A., Freelon, D., Gentzkow, M., Guess, A. M., Iyengar, S., Kim, Y. M., Malhotra, N., Moehler, D., Nyhan, B., Pan, J., Rivera, C. V., Settle, J., Thorson, E., ... Tucker, J. A. (2023). Asymmetric ideological segregation in exposure to political news on Facebook. *Science*, 381(6656), 392–398. <https://doi.org/10.1126/science.ade7138>
- Guess, A. M., Malhotra, N., Pan, J., Barberá, P., Allcott, H., Brown, T., Crespo-Tenorio, A., Dimmery, D., Freelon, D., Gentzkow, M., González-Bailón, S., Kennedy, E., Kim, Y. M., Lazer, D., Moehler, D., Nyhan, B., Rivera, C. V., Settle, J., Thomas, D. R., ... Tucker, J. A. (2023). How do social media feed algorithms affect attitudes and behavior in an election campaign? *Science*, 381(6656), 398–404. <https://doi.org/10.1126/science.abp9364>
- Gutting, R. S. (2020). Contentious activities, disrespectful protesters: Effect of protest context on protest support and mobilization across ideology and authoritarianism. *Political Behavior*, 42(3), 865–890. <https://doi.org/10.1007/s11109-018-09523-8>
- Hokka, J., & Nelimarkka, M. (2020). Affective economy of national-populist images: Investigating national and transnational online networks through visual big data. *New Media & Society*, 22(5), 770–792. <https://doi.org/10.1177/1461444819868686>
- Hopke, J. E., & Hestres, L. E. (2018). Visualizing the Paris climate talks on twitter: Media and climate stakeholder visual social media during COP21. *Social Media + Society*, 4(3), 2056–3051. <https://doi.org/10.1177/2056305118782687>
- Hoppe, T., Van Der Vegt, A., & Stegmaier, P. (2016). Presenting a framework to analyze local climate policy and action in small and medium sized cities. *Sustainability*, 8(9), 847. <https://doi.org/10.3390/su8090847>
- Iyengar, S., Sood, G., & Lelkes, Y. (2012). Affect, Not ideology. *Public Opinion Quarterly*, 76(3), 405–431. <https://doi.org/10.1093/poq/nfs038>
- Kaiser, J., & Puschmann, C. (2017). Alliance of antagonism: Counterpublics and polarization in online climate change communication. *Communication and the Public*, 2(4), 371–387. <https://doi.org/10.1177/2057047317732350>
- Kaur, W., Balakrishnan, V., Rana, O., & Sinniah, A. (2019). Liking, sharing, commenting and reacting on Facebook: User behaviors’ impact on sentiment intensity. *Telematics and Informatics*, 39, 25–36. <https://doi.org/10.1016/j.teles.2018.12.005>
- Kenter, T., & De Rijke, M. (2015). Short text similarity with word embeddings. In *Proceedings of the 24th ACM international on conference on information and knowledge management* (pp. 1411–1420), 2015.
- Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change*, 77(1–2), 45–72. <https://doi.org/10.1007/s10584-006-9059-9>

- Li, Y., & Xie, Y. (2020). Is a picture worth a thousand words? An empirical study of image content and social media engagement. *Journal of Marketing Research*, 57(1), 1–19. <https://doi.org/10.1177/0022243719881113>
- Liu, G.-H., & Yang, J.-Y. (2013). Content-based image retrieval using color difference histogram. *Pattern Recognition*, 46(1), 188–198. <https://doi.org/10.1016/j.patcog.2012.06.001>
- McSwiney, J., Vaughan, M., Heft, A., & Hoffmann, M. (2021). Sharing the hate? Memes and transnationality in the far right's digital visual culture. *Information, Communication & Society*, 24(16), 2502–2521. <https://doi.org/10.1080/1369118X.2021.1961006>
- Meijnders, A. L., Midden, C. J. H., & Wilke, H. A. M. (2001). Communications about environmental risks and risk-reducing behavior: The impact of fear on information processing¹. *Journal of Applied Social Psychology*, 31(4), 754–777. <https://doi.org/10.1111/j.1559-1816.2001.tb01412.x>
- Meyer, D. S., & Staggenborg, S. (1996). Movements, countermovements, and the structure of political opportunity. *American Journal of Sociology*, 101(6), 1628–1660. <https://doi.org/10.1086/230869>
- Modgil, S., Singh, R. K., Gupta, S., & Dennehy, D. (2024). A confirmation bias view on social media induced polarisation during COVID-19. *Information Systems Frontiers*, 26, 417–441. <https://doi.org/10.1007/s10796-021-10222-9>
- Monga, V., & Evans, B. L. (2006). Perceptual image hashing via feature points: Performance evaluation and tradeoffs. *IEEE Transactions on Image Processing*, 15(11), 3452–3465. <https://doi.org/10.1109/TIP.2006.881948>
- Mooseder, A., Brantner, C., Zamith, R., & Pfeffer, J. (2023). (Social) media logics and visualizing climate change: 10 years of #climatechange images on twitter. *Social Media + Society*, 9(1), 2056–3051. <https://doi.org/10.1177/20563051231164310>
- Muraoka, T., Montgomery, J., Lucas, C., & Tavits, M. (2021). Love and anger in global party politics: Facebook reactions to political party posts in 79 democracies. *Journal of Quantitative Description: Digital Media*, 1. <https://doi.org/10.51685/jqd.2021.005>
- Nabi, L., Gustafson, A., & Jensen, R. (2018). Framing climate change: Exploring the role of emotion in generating advocacy behavior. *Science Communication*, 40(4), 442–468. <https://doi.org/10.1177/1075547018776019>
- Pearce, W., Özkula, S., Greene, A., Teeling, L., Bansard, J., Omena, J., & Rabello, E. (2020). Visual cross-platform analysis: Digital methods to research social media images. *Information, Communication & Society*, 23(2), 161–180. <https://doi.org/10.1080/1369118X.2018.1486871>
- Qian, S., Lu, Y., Peng, Y., Shen, C. C., & Xu, H. (2024). Convergence or divergence? A cross-platform analysis of climate change visual content categories, features, and social media engagement on twitter and Instagram. *Public Relations Review*, 50(2), 102454. <https://doi.org/10.1016/j.pubrev.2024.102454>
- Ross, A. S., & Rivers, D. J. (2019). Internet memes, media frames, and the conflicting logics of climate change discourse. *Environmental Communication*, 13(7), 975–994. <https://doi.org/10.1080/17524032.2018.1560347>
- Rossi, L., Neumayer, C., Henrichsen, J., & Beck, L. K. (2023). Measuring violence: A computational analysis of violence and propagation of image tweets from political protest. *Social Science Computer Review*, 41(3), 905–925. <https://doi.org/10.1177/08944393211055429>
- Sanford, M., Witkowska, M., Gifford, R., & Formanowicz, M. (2023). Emotional framing in online environmental activism: Pairing a twitter study with an offline experiment. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.1099331>
- Spartz, J. T., Su, L. Y.-F., Griffin, R., Brossard, D., & Dunwoody, S. (2017). YouTube, social norms and perceived salience of climate change in the American mind. *Environmental Communication*, 11(1), 1–16. <https://doi.org/10.1080/17524032.2015.1047887>
- Staggenborg, S., & Meyer, D. S. (2022). . Understanding countermovements. In D. Tindall, M. C. Stoddart, & R. E. Dunlap (Eds.), *Handbook of AntiEnvironmentalism*. Edward Elgar Publishing. <https://doi.org/10.4337/9781839100222.00009>
- Tandoc Jr, E. C., & Eng, N. (2017). Climate change communication on Facebook, Twitter, Sina Weibo, and other social media platforms. In *Oxford research encyclopedia of climate science*. Oxford University Press. <https://oxfordre.com/climatescience/view/10.1093/acrefore/9780190228620.001.0001/acrefore-9780190228620-e-361>.
- Tomczak, M., & Tomczak, E. (2014). The need to report effect size estimates revisited. An overview of some recommended measures of effect size. *TRENDS in Sport Sciences*, 1(21), 19–25.
- Treen, K., Williams, H., O'Neill, S., & Coan, T. G. (2022). Discussion of climate change on reddit: Polarized discourse or deliberative debate? *Environmental Communication*, 16(5), 680–698. <https://doi.org/10.1080/17524032.2022.2050776>
- Tyagi, A., Uyheng, J., & Carley, K. M. (2020). *Affective polarization in online climate change discourse on Twitter*. In IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM), pages 443–447. IEEE, 2020.
- Vaccari, C., & Valeriani, A. (2021). *Outside the bubble: Social media and political participation in western democracies*. Oxford studies digital politics series. Oxford University Press.
- Van der Maaten, L., & Hinton, G. (2008). Visualizing data using t-SNE. *Journal of Machine Learning Research*, 9(11), 2579–2605.

- van Eck, C. W. (2024). Opposing positions, dividing interactions, and hostile affect: A systematic review and conceptualization of “online climate change polarization”. *WIREs Climate Change*, e906. <https://doi.org/10.1002/wcc.906>
- Van Eck, C. W., Mulder, B. C., & Van Der Linden, S. (2021). Echo chamber effects in the climate change blogosphere. *Environmental Communication*, 15(2), 145–152. <https://doi.org/10.1080/17524032.2020.1861048>
- Von Sikorski, C. (2022). Visual polarisation: Examining the interplay of visual cues and media trust on the evaluation of political candidates. *Journalism*, 23(9), 1900–1918. <https://doi.org/10.1177/1464884920987680>
- Wang, S., Corner, A., Chapman, D., & Markowitz, E. (2018). Public engagement with climate imagery in a changing digital landscape. *WIREs Climate Change*, 9(2), e509. <https://doi.org/10.1002/wcc.509>
- Wetherell, M. (2012). *Affect and emotion: A New social science understanding*. SAGE Publications Ltd. <https://doi.org/10.4135/9781446250945>
- Williams, H. T., McMurray, J. R., Kurz, T., & Hugo Lambert, F. (2015). Network analysis reveals open forums and echo chambers in social media discussions of climate change. *Global Environmental Change*, 32, 126–138. <https://doi.org/10.1016/j.gloenvcha.2015.03.006>
- Won, D., Steinert-Threlkeld, Z. C., & Joo, J. (2017). Protest Activity Detection and Perceived Violence Estimation from Social Media Images. In *Proceedings of the 25th ACM international conference on Multimedia, MM '17*, pp. 786–794, Mountain View, California, USA, 2017. Association for Computing Machinery. doi:10.1145/3123266.3123282.
- Yarchi, M., Baden, C., & Kligler-Vilenchik, N. (2021). Political polarization on the digital sphere: A cross-platform, over-time analysis of interactional. *Political Communication*, 38(1-2), 98–139. <https://doi.org/10.1080/10584609.2020.1785067>
- Yuan, S., & Lu, H. (2020). “It’s global warming, stupid”: Aggressive communication styles and political ideology in science blog debates about climate change. *Journalism & Mass Communication Quarterly*, 97(4), 1003–1025. <https://doi.org/10.1177/1077699020904791>